

Appendix 2

Best Practices

In the Development of Simulation Scenarios

For Validation Activities in Fast and Real-Time Simulation

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Executive Summary

The second Federal Aviation Administration (FAA)/EUROCONTROL Action Plan 5 Validation and Verification Strategy Workshop, held in conjunction with Action Plan 9 Air Traffic Modeling of Operational Concept, was conducted on March 11-13, 2003, to develop and standardize 'best practices' related to the development of simulation scenarios for validation exercises. The workshop was well attended by 32 European and 19 United States (US) practitioners, all of whom were experienced in fast-time and real-time simulation for concept validation. The workshop focused on the development of simulation scenarios for both fast-time and real-time simulation and covered the following topic areas:

1. Coordination of Fast & Real-time Simulation Activities
2. Scenario Uses
3. Scenario Considerations
4. Traffic Building
5. Specific Event Scripting
6. Analysis Considerations

Practitioners introduced each of the topic areas with a short briefing, which was then followed by a discussion session facilitated by a moderator. After the initial discussions on each topic, practitioners were divided into working groups to further discuss and identify elements of best practices for the topics to which they were assigned. Their consolidated recommendations were presented to all workshop participants for final discussion and consensus.

The resultant best practices for developing and validating simulation scenarios are presented in this appendix. Their purpose is to serve as supplemental guidelines for experienced practitioners who perform concept validation activities. Additional material concerning scenario development and coordination of fast and real-time activities outside the scope of the topic areas listed above is also included in this appendix, based on discussions held during the workshop.

Overall, the participating practitioners felt that the workshop was very valuable and useful for their research endeavors. They suggested that further workshops be arranged to discuss additional topics such as Metrics and Measures, more specific topics on Scenario Development, and Reporting Results.

1 Background

The Federal Aviation Administration (FAA)/EUROCONTROL R&D Committee was established in December 1995 during the second FAA/EUROCONTROL R&D Symposium, held in Denver, Colorado. The focus of the FAA/EUROCONTROL R&D Committee was to define priorities in terms of common actions and agendas of both organizations. The Committee identified areas of mutual interest where the FAA and EUROCONTROL could work together in R&D and defined several R&D Cooperative Tasks, which are referred to as 'Action Plans'.

The goal of Action Plan 5 (AP5) is to determine a unified strategy for validating and verifying the performance, reliability, and safety of Air Traffic Management (ATM) systems. One objective of Action Plan 9 (AP9) is to promote a mutual understanding between the United States (US) and Europe on the use and development of fast-time simulation models for modelling of air traffic operational concepts. An objective shared by AP5 and AP9 is to develop detailed best practices for performing tasks associated with the verification and validation of ATM systems. The development and subsequent use of these best practices will allow for sharing of information and comparison of results among all researchers. Best practices covering the use of metrics, data collection, data analysis, and reporting are useful for each type of validation exercise, as they take into account several factors including resources, cost, and most importantly, prior 'lessons learned'.

In order to capture 'lessons learned' from a range of research organizations, several workshops were conducted and more will follow. The attendees of these workshops include experienced practitioners in their respective fields and in the topics presented at the workshops. This appendix describes the best practices resulting from the Second US/Europe Practitioners' Workshop, where the topic for discussion was the development of fast- and real-time simulation scenarios for validation activities.

2 Second US/Europe Practitioners' Workshop on best practices in the development of fast-time and real-time simulation scenarios for validation activities.

The FAA and EUROCONTROL organized the second AP5 workshop in conjunction with AP9. The workshop took place in March 2003 in Rome, Italy. The objective of this second workshop was to discuss and identify best practices from practitioner experience in the development of simulation scenarios for validation activities.

During ATM concept validation, both fast-time and real-time simulation techniques are used. These techniques require the development of scenarios, but at present, no standardized guidelines exist to steer the researcher through the development of these scenarios. During this workshop, researchers identified best practices based on actual experiences in developing scenarios. The best practices presented in this document pertain to both fast- and real-time techniques. Those that are unique to fast- and real-time techniques are identified as such. In addition, relevant best practices from the Operational Concept Validation Strategy Document (OCVSD) Appendix 1 ("Best Practices for Human-in-the-Loop Validation Exercises"), hereafter referred as Appendix 1, are also included where appropriate.

The Second Workshop participants included 19 practitioners from the US and 32 practitioners from Europe representing both fast-time and real-time simulation fields. The US participants included researchers from the FAA William J. Hughes Technical Center, National Aeronautics and Space Administration (NASA) Ames Research Center, NASA Langley Research Center, Volpe Transportation Research Center, MITRE, BAE systems, Embry-Riddle Aeronautical University (ERAU), Logistics Management Institute (LMI), CNA Corporation, CSSI, San Jose State University, and TransSolutions.

The Europe participants included researchers from Aeropuertos Españoles y Navegación Aérea (AENA), Deutsche Flugsicherung GmbH (DFS), Direction Générale de l'Aviation Civile (D.G.A.C.), Sistemi Innovativi per il Controllo del Traffico Aereo (SICTA), Deutschen Zentrum für Luft- und Raumfahrt (DLR), EUROCONTROL, EUROCONTROL Experimental Centre, Frankfurt Airport Services Worldwide (Fraport), Deep Blue, Ente Nazionale di Assistenza al Volo (ENAV), Centre d'Etudes de la Navigation Aérienne (CENA), ISA Software, National Air Traffic Services (NATS), OECD Halden Reactor Project, and Nationaal Lucht en Ruimtevaartlaboratorium (NLR).

3 Relevant Terms & Definitions

3.1 Simulation Definitions

Because fast-time and real-time simulations are distinct approaches, each technique has its own terminology, data, and validation strategies. To clarify some of the differences, this section contains a definition of terms.

3.1.1 Real-Time Simulation

A real-time simulation is one in which a human operator (e.g., air traffic controller) interacts with and reacts to simulated conditions in near real-time.

3.1.2 Fast-Time Simulation

A fast-time simulation is one in which there is no interactive human involvement in simulated conditions. Instead, scenarios unfold using rule-based decisions that control the interactions between simulated actors.

Note: There are hybrid simulation techniques, which allow human interaction, but do not have to run in real-time. For purposes of this appendix, these techniques are classified under fast-time simulation.

3.2 Scenario Definitions

Scenarios are well recognized as an important tool for assessing the impact of proposed changes on the ATM system, and in the case of human-in-the-loop studies, on human performance. There are different views on the definition of scenario, depending on the context in which the term is being used. The following paragraphs define the term ‘scenario’ within various contexts. In ATM, the two most common definitions refer to Operational Concept Scenarios and Validation Scenarios.

3.2.1 Operational Concept Scenario

An operational concept scenario is a documented description of a sequence of events involving one or more ‘actors’ that is focused on some specific ATM function or procedure. This type of scenario is generally implemented during initial concept design and development phases. It allows various instances to be described during the identification and refinement of issues for further testing and development. An operational concept scenario used in concept design can be used to describe various “what if” scenarios in order to judge or explain how a concept should work in these instances. Such a description is likely to be generic in nature, not requiring specific details of the environment.

The following example is taken from a Principles of Operations document for an En-Route concept using System Supported Co-Ordination (SYSCO). While the example is detailed, the generic description and general applicability of this description should be noted:

“Sector 1 is an enclosed sector bordered on either side and to the south by sector 2, and on either side and to the north by sector 3. All sectors are en-route sectors; S1 has a TMA below for traffic routing to/from a small airport at point C3. Aircraft ABC1 has a planned routing from point A1 along route A to exit the sector at point A4, continuing on to point A5 and beyond. Aircraft ABC2 has a planned routing from point B1 to point B3, before joining route C to land at point C3. Both aircraft are cruising at their RFL of FL340 and are of similar type.

The scenario begins with ABC1 in S2 approaching S1, and with ABC2 in S3 approaching S1. Prior to sector entry S1's system has received, via SYSCO messages, advanced warning information of ABC1 & ABC2 from S2 & S3 respectively. Both upstream sectors have a LoA with S1 and both aircraft are complying with the conditions of the agreement. Because of this, the SYSCO systems have automatically generated and agreed upon entry/exit conditions compliant with the LoA. Therefore, no explicit co-ordination task has taken place and the system dialogue has remained transparent to both sets of sector controllers”

3.2.2 Validation Scenario

A validation scenario is an extension of the operational concept scenario. It is a representation of the events, actors, and interactions of the operational scenario applied in a simulation environment. The objective is to excite the performance and interactions described or expected in the operational scenarios. The simulation environment refers to various configurations of airspace, traffic sample, weather, failure modes, and any other controllable variables that might affect the performance of the ATM system. In this way, a validation scenario will test the assumptions in the concept scenarios and thus the concept design.

The validation scenario is that which is actually implemented in a simulation in order to provide robust feedback in terms of whether or not a proposed concept can be implemented in the operational environment. Validation scenarios are actually run in the experiments, therefore they will require specific traffic files, airspace files, and possibly scripted events in order to execute properly. They will also have associated validation objectives and be able to address specific indicators and metrics.

3.3 Scenarios in Simulations

There are several types of scenarios; each takes on a different meaning. The following definitions distinguish the various scenario terms.

3.3.1 Real-Time Simulation Scenario

A scenario for a real-time simulation is generally characterized by a specific or generic geographical environment, traffic sample, and special scripted events, such as weather. A variety of scenarios may be developed for a real-time activity in order to gain generality in the results. For example, traffic samples may vary by volume to test the limits of the human operators with new concepts, procedures, and/or equipment. In general, scenarios in real-time simulation are meant to challenge the human operator in some or all aspects of the system. They are used to allow for measurement of workload, for example, of a new concept on an air traffic controller.

3.3.2 Fast-Time Simulation Scenario

A scenario for a fast-time simulation is characterized by a given set of conditions that include a specific geographic environment (e.g., airspace, airport), traffic sample, event or set of events, procedures, and any other controllable variables (e.g., weather, failure modes) that are of interest to the outcome of the simulation. Scenarios in fast-time simulation typically represent normal operating conditions of a new concept for analysis. In other words, if a new procedure is being evaluated, the fast-time model runs assuming the procedure performs without fail throughout the scenario. This is an effective approach when predicting potential capacity gains, for example, of a new concept.

3.3.3 Baseline Scenario

A baseline scenario is a reference scenario that provides a benchmark against which the effects of the experimental conditions (i.e., proposed operational concepts) can be evaluated. The baseline scenario establishes a point of comparison. It implements the scope and control conditions for testing of the hypothesis. It does not implement the experimental conditions.

4 Scenario Uses

Scenarios are a core component of many types of evaluations and simulations. Their application is not limited to any one type or level of testing. Rather, they can provide the basis for exploratory studies, demonstrations, usability testing, and operational test and evaluation activities. The objectives of scenario use and the actual way in which they should be used can change with increasing maturity in the concept development. This section begins by discussing the use of scenarios in the typical Concept Validation stages (V1-V3) and is based on the levels of maturity outlined in the OCVSD.

4.1 Scenarios and Levels of Maturity

4.1.1 V1 Establishment of Concept Principles

In the earliest stages of concept development, the concept designers will not have a well-formed idea of the concept principles or operational and technical requirements. The scenarios at this stage will be focused on understanding the potential of the concept. The purpose at this stage is to help form the principles, eliminate poor design choices, and focus on refining the concept. Scenarios will be focused on establishing the scope of the concept.

4.1.2 V2 Proof of Concept

In the next stage of development, basic assumptions should already have been tested and basic design already formulated. At this level, scenarios should focus on more advanced aspects of the concept design, proof of use, non-nominal cases or marginal capabilities. At this stage, there may still need to be a repetition of the type of analysis performed after V1, but mainly the scenarios here will not be so singularly focused. The outcome of this stage in the validation process should be a mature, stable concept design with an initial proof of concept. Scenarios will be focused on setting the limits of the concept, establishing

procedures and phraseology and determining clear requirements to assist in producing a stable environment for the final pre-implementation phase.

4.1.3 V3 Concept Integration and Pre-Ops Trials

In the final stage of the concept development, the scenarios will focus on repetition, replication, and performance measurement. The experiments here will be assessing a mature concept in rigorous, high fidelity experiments (large fast-time or real-time). As such, the scenario will need to be designed with choice of indicators and metrics in mind. Large detailed scenarios will be built to model the whole system under assessment. The scenarios will need to be run repeatedly in order to generate enough data for performance measurement, with baseline scenarios taken into consideration. The outcome of this stage in the validation process will be detailed information about the expected performance of the system under a variety of normal conditions and the ability of the system to cope with various non-normal conditions.

4.2 Scenario Objectives

4.2.1 Exploration

Scenarios can be used to develop and refine a concept and explore what-if questions. Methods suitable to meeting these objectives include cognitive walkthroughs, part task simulations, and fast-time simulations. Exploratory scenarios are generally a low-cost means of identifying issues and refining the experimental approach for future studies on a proposed operational concept.

4.2.2 Demonstration

Scenarios can be used to show or exhibit a potential capability to a targeted audience. They can be incorporated into demonstrations, which although do not prove a concept, can give interested parties a view of how a concept might appear in the operational environment. With demonstrations, researchers may have to forego strict experimental design – e.g., procedures may evolve as demonstration progresses, but this does not undermine the value of the information gained from the demonstration.

4.2.3 Usability Testing

Scenarios created for usability testing can help to determine the appropriateness of a proposed tool, procedure, and/or equipment. Usability testing typically examines user preference and performance for a specific use, and thus scenarios are generated correspondingly to address issues associated with the proposed concept.

4.2.4 Operational Trial

Operational trial scenarios are used to confirm that the ‘system’ under test performs to predetermined standards and/or criteria when stressed. The operations trial scenario is designed to elicit performance to the level that it demonstrates the system works as expected under all foreseen exceptions and failure modes. It is also designed to answer questions

related to the expected benefits and expected costs of implementing a new concept. A trial may involve a variety of scenarios in order to gain generality and statistical relevance in the results. The number of scenarios or number of concept relevant events in those scenarios needs to be derived from the required statistical relevance.

5 Steps in Scenario Design

The following outline reviews the basic steps to be carried out when designing scenarios. The steps are iterative in nature, and as such should be continually applied as the concept matures.

1. Clearly define simulation objectives
 - Consider concept level of maturity
 - Consider operational understanding
 - Obtain stakeholder input
2. Identify and prioritize appropriate metrics/ evaluation criteria
3. Determine relevant scenario characteristics
 - Bear in mind that scenarios should cover a variety of dimensions: normal to abnormal, simple to complex, low to high taskload, and procedural tasks versus problem solving
 - Consider including a wide range of scenarios to allow for greater generalization of results
 - Consider a range of scenario characteristics, including the following:
 - Domain
 - Scope
 - Duration
 - Fidelity
 - Focal points
 - Experimental validity
 - Human performance requirements
 - Obtain stakeholder input
4. Determine assumptions and limitations
5. Identify data management and analysis requirements
6. Prepare detailed reports
 - Document assumptions and limitations and their implications on the results
 - Obtain stakeholder input

6 Coordination of Fast & Real-Time Simulation Activities

Table 1 presents a list of recommended best practices to be considered when coordinating scenarios between fast-time and real-time simulation activities. Each best practice is described in more detail following the table.

Table 1 - Best Practices for Coordination of Fast & Real-Time Scenario Development

6	Coordination of Fast & Real-Time Simulation Activities
bp 2-1	Communicate with fellow fast-time and real-time researchers
bp 2-2	Clearly state and document your design assumptions
bp 2-3	Clearly state the likely implications of your assumptions
bp 2-4	Standardize scenarios for use in both fast- and real-time simulations when possible

Traditionally validation has taken the approach suggested in the Validation Route Map, that first you do fast-time, followed by a real-time simulation (see Section 5.2 of the OCVSD). Although not as customary, one approach is to perform real-time experiments, followed by fast-time. In reality, there is no set pattern on which validation technique should follow which, providing the selected one is appropriate. A thorough analysis actually involves multiple iterations using different types of evaluation tools. The "Banana Model" provides a good basic illustration of this process, but it presents the illusion that it is a one-way flow. In fact, there are two-way flows to every node in the model. With each iteration, the researcher uses information gained from the previous analysis, revisits assumptions and inputs, refines approaches, and selects the appropriate tool for future analysis.

When considering the coordination of fast-time and real-time validation techniques, the link between them should reflect the iterative nature of the relationship, as demonstrated in Figure 1. This iterative approach suggests the need for greater coordination in the design, development and use of scenario. It allows for a common structure that supports data sharing and re-using information where possible. It is the aim of the best practices presented in this document to promote this coordination.

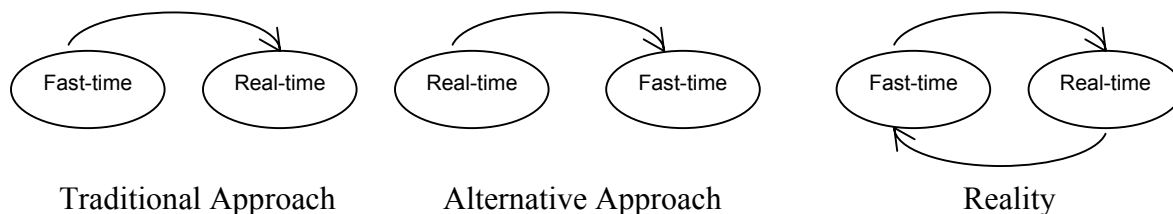


Figure 1 - Iterative nature of fast- and real-time analyses.

6.1 Data Sharing and Re-Use between Fast-Time & Real-Time

Data sharing between fast- and real-time simulations can occur in two forms: one focuses on the data input, and one focuses on data output.

The first type of data sharing concerns data originating from a single source that can be used as input into the scenario design for both fast- and real-time simulations. The benefits of

using common data sources are faster scenario development times, common baselines, and the ability to compare results.

The second form of data sharing concerns the re-use of data used or produced by another/previous simulation. Such data could include the following:

- System performance, user response times, variability data
- Human error models
- Trajectory prediction inaccuracy, aircraft position inaccuracy
- Event or series of events that alter the flow of aircraft
- Traffic forecast for target years
- Baseline measures (in terms of traffic, airspace, procedures, roles and responsibilities, operators, etc.)

The researcher should always use caution when considering sharing data in either form. He/she must ask questions: Are the chosen inputs and metrics suitable in both types of simulations? Is the specific type of data produced in the real-time simulation (e.g., controller response times) realistic enough to put into the fast-time model? What impact would a learning effect demonstrated in a real-time simulation data have on the fast-time model? Could the fast-time model erroneously magnify or overstate any of the impacts demonstrated in the real-time?

To combat these risks, this document proposes the following best practises.

Certain software packages are already under development with the aim of combining the characteristics of the fast-time and real-time simulation techniques. This development highlights the need for greater coordination in scenario development and the need for a common structure and leads to the first Best Practice recommendation in this document.

bp 2-1. Communicate with fellow fast-time and real-time researchers

In the interest of better coordination, those working on real-time simulations and those working on fast-time simulations should communicate and interact with each other regarding their work. Often the two parties are working independently on the same or similar issues. However, they should communicate about their efforts and share information on such issues as assumptions, results, and lessons learned.

bp 2-2. Clearly state and document your design assumptions

One of the difficulties in coordinating fast and real-time simulation activities and sharing data is the different types of assumptions that go into each, which can cause problems when trying to share or re-use data. As such, it is very important that both fast and real-time researchers clearly state their assumptions before performing their analyses. Perhaps a common template could be developed. That way any researcher could look at the template, and identify and understand the assumptions. This is vital for interpretation.

bp 2-3. Clearly state the likely implications of your assumptions

The researcher should state not only what the design assumptions are, but also what the implications of the assumptions are. This helps in the correct interpretation of a model, and is particularly important if the assumptions are implicit. Documentation of the assumptions and implications is recommended to provide traceability by showing which outputs came from which sources, what assumptions affected what outputs, etc.

bp 2-4. Standardize scenarios for use in both fast- and real-time simulations when possible

To help facilitate coordination between scenario development in fast-time and real-time simulations, a standardized scenario development process and characterization scheme could be developed. These could be designed around each technique with common processes and areas noted for coordination purposes. This would be useful for designing scenarios, building scenarios, and possibly even comparing results after the simulations.

6.2 Technology Advancement

Due to the different objectives of fast-time and real-time simulations and the differing techniques and expertise involved for each, coordination historically between fast-time and real-time has not been easy. It can be difficult to model certain concepts in the fast-time environment due to limitations in computer processing speeds, computer memory, or the fast-time models themselves. For example, fast-time simulation is weak when modelling human performance, such as in the case of Collaborative Decision Making (CDM). A view has been taken that some concepts just are not suitable for evaluation in the fast-time environment. Part of the problem has been that the fast-time simulation technology has not evolved to a level suitable to simulate the concepts. Emerging technologies, however, may solve this problem. Fast-time simulation software is continually under development and may in the future be used increasingly for what were traditionally subjects for real-time assessments only. Researchers may see more hybrid fast-time/real-time models in the years to come.

7 Scenario Development Considerations

Table 2 presents a list of recommended best practices to be considered when developing and designing scenarios. Each best practice is described in more detail following the table.

Table 2 - Best Practices for Scenario Development and Design

7	Scenario Development Considerations
bp 2-5	Allow the research questions to drive scenario development
bp 2-6	Map out and prioritize all potential scenario characteristics
bp 2-7	Identify and maintain common scenario characteristics for comparison
bp 2-8	Check that the test environment can support your scenarios and be prepared to make compromises
bp 2-9	Start with a baseline derived from current information (including traffic)
bp 2-10	Consider options such as “generic airspace”
bp 2-11	Seek subject matter expertise during the development of your scenarios
bp 2-12	Obtain involvement from all stakeholders during scenario design
bp 2-13	Define and maintain necessary levels of realism
bp 2-14	Strike a balance in the order of the scenario presentation
bp 2-15	Scenarios should carefully isolate key technologies that require large capital investments in order to be clear on potential benefits
bp 2-16	A common list of scenario characteristics should be formed

Researchers have many factors to consider when designing scenarios. They know that carefully designed scenarios produce the most useful test results and that poorly crafted scenarios can preclude the achievement of test objectives. As such, the following section provides guidance on points to consider in the scenario development process.

bp 2-5. Allow the research questions to drive scenario development

While the researcher should strive to develop scenarios that model the operational environment, it is crucial to build scenarios to address the research questions and objectives. All perspectives (researcher, operational, and management) should be taken into consideration.

This Best Practice is taken from Appendix 1 (bp 1-16). For more information, please refer to the text in that appendix.

bp 2-6. Map out and prioritize all potential scenario characteristics

Scenarios can be characterized on several different levels; by concept aspects (roles, procedures, and sequence of tasks), environment aspects (airspace, route structure, traffic volume), and event aspects (normal events, non-normal events). The researcher should

develop a scheme to map out and prioritize potential scenario characteristics to aid in the development process.

bp 2-7. Identify and maintain common scenario characteristics for comparison

One of the biggest challenges in scenario development is to create scenarios that are experimentally comparable, but that are different enough to present a “new” problem. Experimenters often have to design scenarios that are similar (in complexity) but not exactly same. Similar scenarios are an essential part of a good experimental design as they help with statistical comparisons.

However, in real-time simulation, scenarios that are similar could also produce undesirable learning effects. The learning effects could negate the effects of the experimental conditions. Simply changing the aircraft call signs is not always adequate since controllers can often recognize similar air traffic patterns. Learning effects can be controlled somewhat by randomizing the order of experimental conditions.

This Best Practice is taken from Appendix 1 (bp 1-17). For more information, please refer to the text in that appendix.

bp 2-8. Check that the test environment can support your scenarios and be prepared to make compromises

In keeping with the FAA / EUROCONTROL principles of concept levels of maturity (V1 to V5), scenarios should become more mature and rigorous as the concept becomes more mature. If the scenario changes, ensure that the simulation environment is capable of supporting the scenario requirements and can deliver the data needed to feed the selected performance metrics.

bp 2-9. Start with a baseline derived from current information (including traffic)

Baseline traffic samples should be derived from current traffic data. The use of baselines developed from past information should be avoided. Procedures, tools, and traffic schedules continuously change; therefore obtaining current information helps establish a more realistic baseline.

There are some exceptions to this best practice in the fast-time environment since one has the ability to create a future baseline based on known future improvements. For example, if a runway is to be in place at an airport a year from now, modelling the current airport will have no value in comparing any new improvements.

bp 2-10. Consider options such as “generic airspace”

This Best Practice is taken from Appendix 1 (bp 1-15). For more information, please refer to the text in that appendix.

bp 2-11. Seek subject matter expertise during the development of your scenarios

The researcher should acquire subject matter expertise from air traffic control specialists, pilots, operational personnel, and/or individuals familiar with the domain of interest and corresponding traffic characteristics to assist in the development of scenarios. SMEs can help build and validate the scenarios. For example, they can assist the researcher in determining the number of scenarios required to achieve the desired simulation results. They can also point out weaknesses in the scenarios that may lead to incomplete data or missed opportunities. Having an SME participate in the scenario development process will add credibility and fidelity to any simulation effort.

bp 2-12. Obtain involvement from all stakeholders during scenario design

The researcher should try to obtain input from the various stakeholders involved with a simulation. Sponsors and potential users of the operational concept under test, airport and airline representatives, and when possible, Airline Operation Center personnel, are key to gaining buy-in of simulation results. This best practice not only applies to scenario development, but to the entire simulation effort.

bp 2-13. Define and maintain necessary levels of realism

While developing scenarios, researchers are usually interested in maintaining high realism related to aircraft mix, traffic density, sector geometry, routes, and procedures. Many times, the scenario development process starts with the collection of actual operational flight plan data, which provides the realism. The operational data with realistic traffic density and aircraft types works well for near-term initiatives. However, for future concepts, operational data may need considerable modifications in order to satisfy the experimental objectives. In such situations, a number of variables, such as future traffic load, future aircraft mix, and technologies may need to be modified.

This Best Practice is taken from Appendix 1 (bp 1-19). For more information, please refer to the text in that appendix.

bp 2-14. Strike a balance in the order of the scenario presentation

In real-time simulation sound experimental design calls for randomization of scenario presentation, however, over-randomization can lead to an unfair variance in the results. Researchers should keep in mind that controllers are accustomed to a certain 'order' in their work. Over-randomizing the scenarios is unnatural. On the other hand, presenting scenarios in too similar of an order can lead to over-familiarization, or a learning effect. Balance is required. This is a problem in real-time, but not in fast-time, as a computer will not 'learn' the sample.

bp 2-15. Scenarios should carefully isolate key technologies that require large capital investments in order to be clear on potential benefits

When developing scenarios that require an assessment of multiple concepts, it is essential that you isolate the effects and performance changes of each concept, thereby making clear the benefits of each. There are certain concepts that require a large investment in time and resources, therefore the cost/benefit analysis must show the benefit of these particular concepts without the additional or cumulative affects of any other concept in your scenario.

bp 2-16. A common list of scenario characteristics should be formed

Most concept validation simulations are performed based on a single set of scenario conditions and does not take into account many aspects of the Air Traffic Control (ATC) environment. A solution to this problem would be to develop a common set of scenario characteristics based on the type of simulation performed.

For example, at a minimum you should be required to perform one bad weather scenario, one runway change, one go around, and one level bust. Granted, this solution does not always fit; time, resource, and cost can significantly influence how many scenarios can be run.

Regardless, the use of such a list will enable some cross-referencing among different concepts or simulations. It is also particularly useful when assessing concepts of higher maturity by way of providing a set of 'bench-mark' tests.

8 Traffic Building

Table 3 presents a list of recommended best practices to be considered when building traffic for scenarios. Each best practice is described in more detail following the table.

Table 3 - Best Practices for Building Traffic

8	Building Traffic
bp 2-17	Starting and/or ending scenarios slowly is not usually efficient
bp 2-18	Traffic peaks and troughs may be relevant to research
bp 2-19	Validate aircraft performance
bp 2-20	Don't exceed the airport projections when projecting enroute or terminal growth
bp 2-21	Consider city pairs, when possible
bp 2-22	Translate yearly forecasts (peak) into daily and hourly operations
bp 2-23	Try to identify aircraft types and mix

Developing scenarios usually involves a large investment in time and cost. The majority of time spent developing scenarios is in building the traffic sample. A 'basic' traffic sample is not so hard to develop, but a large percentage of time is spent on ensuring the appropriate realism of the sample. For fast-time studies (e.g. RAMS), about 20-30% of the total effort is spent on traffic preparation.

bp 2-17. Starting and/or ending scenarios slowly is not usually efficient

In real-time simulation, a common way of building a scenario is to initiate traffic gradually into the problem, allowing the controllers to ease themselves into the scenario. When the main part of the scenario is over, traffic usually tapers off. For an hour-long scenario, as much as 15 minutes on either end of the scenario might be dedicated to “ramp up/down” time. Given the time and cost restraints to run a simulation, this is not the most effective or efficient use of scenario time. A more efficient means of building a scenario is to begin with a normal traffic load. Depending on the study, practitioners may also end the scenario in the middle of a conflict or other problem.

This Best Practice is taken from Appendix 1 (bp 1-18). For more information, please refer to the text in that appendix.

bp 2-18. Traffic peaks and troughs may be relevant to research

In real-time simulation, HITL practitioners often try to impose high workload levels on simulation participants to stretch the limits of the participant’s abilities and to test the limits of new concepts and procedures on the air traffic system. To do this, they typically design traffic scenarios to represent peaks or high levels of traffic activity. Slower-manifesting problems are generally avoided since the practitioner wants to make the best use of valuable time. Prior simulation research has shown, however, that operational errors often occur in the beginning of troughs, or lower levels of traffic, immediately following very high levels of traffic activity (this results because of a temporarily perceived reduction of complexity and thus lower vigilance). In order to better emulate the operational environment and capture all possible conditions for human error, HITL practitioners should script a range of traffic activity into their scenarios; those which include both peak levels of traffic and troughs.

This Best Practice is taken from Appendix 1 (bp 1-20). For more information, please refer to the text in that appendix.

bp 2-19. Validate aircraft performance

In real-time simulation, the validation of aircraft performance is very important because in general there is a greater need for realism. This is especially true if the purpose of the study is to assess the impact of a new aircraft type. Realistic aircraft performance is a key element in helping the participants to work in their normal manner, although there may be occasions where a lower level of realism can be acceptable. It is recommended that during scenario development SMEs (i.e., controllers) observe the aircraft movements to validate their realism.

In fast-time simulation, the required degree of realism will depend on the purpose of the study. Queuing models may need nothing more than aircraft speed, while algorithms that are more complex are needed for conflict prediction and resolution.

The standardization of aircraft performance in trajectory prediction is being investigated by other organizations; however, realism of aircraft performance continues to be an issue.

bp 2-20. Do not exceed the airport projections when projecting en route or terminal growth

When developing traffic samples, do not exceed the level of traffic that is projected for the origin or destination airports. Exceeding the level of traffic at the origin or destination airport will cause unrealistic delays and throughput in the airspace system. For example, do not have 80 aircraft per hour flying between airports with a 35 aircraft per hour capacity.

bp 2-21. Consider city pairs, when possible

A common practice in today's environment is to simulate each airport or section of airspace as a stand-alone system, without taking into account the affects on certain city pairs. When generating traffic samples, the origin and destination airports must be able to handle the level of traffic that is projected for each. Traffic should be adjusted based on terminal area forecasts and/or other business models, to provide a realistic future traffic sample. Certain models or simulators require city pairs to execute properly, so having city pair information will aid in re-use and/or real-time/fast-time coordination. Finally, traffic generated for a certain city could be used in metro area analysis.

bp 2-22. Translate yearly forecasts (peak) into daily and hourly operations

For most simulations, yearly forecasts must be translated into daily and hourly operations. To do this, a baseline of current traffic should be developed through data gathering and adjusted based on traffic forecast. These techniques need examination since they have not been perfected or standardized, especially when it comes to smoothing peak periods of traffic.

A point of caution here is to take abnormal peaks or troughs into account. For various reasons traffic levels may experience an abnormal growth at certain times (e.g., an annual major event in the area). Such occasions, although not normal, should be considered.

bp 2-23. Try to identify aircraft types and mix

Environmental studies require the analysis of specific aircraft types especially during noise studies, so identifying individual aircraft types and establishing a fleet mix is essential. Some simulations only require aircraft groups or classes, but when the traffic sample is used in other simulations, it becomes very difficult to re-engineer without specific knowledge of aircraft types and composition of fleet mix. Identifying individual aircraft types also helps in coordination between fast and real-time simulations.

9 Specific Event Scripting

Table 4 presents a list of recommended best practices to be considered when scripting events. Each best practice is described in more detail following the table.

Table 4 - Best Practices for Scripting Specific Events

9	Scripting Specific Events
bp 2-24	Plan more scripted events than you need to ensure desired results
bp 2-25	Prepare participants as necessary
bp 2-26	Do not try to script operational errors
bp 2-27	Consider scripting system-wide events
bp 2-28	Consider the use of dynamic scripting

A scripted scenario is one that deliberately introduces a disturbance into the system. Such a disturbance is generally known in advance to the validation team but not the simulation participants. Scripted scenarios are particularly useful for assessing the impact of 'unplanned' events in a simulation environment where if you did not deliberately introduce them, you would probably not encounter these (often critical) situations.

bp 2-24. Plan more scripted events than you need to ensure desired results

When accessing a certain operational concept, you may have certain events happen to show the benefits of the concept. In this situation, you should plan more scripted events than needed to ensure desired results. For example, script nine potential conflicts to obtain at least four. However, adding more events should not compromise realism.

bp 2-25. Prepare participants as necessary

In real-time simulation, it is usually advisable to prepare participants about potential events they may encounter in the simulation. However, any pre-warning should be kept to a minimum, since you still require controllers to work normally and not in a contrived manner.

For example, consider the case where a simulation is investigating a future concept, such as the effects of a catastrophic failure of the Global Positioning Satellite (GPS) system when it is used as a sole source of navigation. Because controllers to date have never used GPS as a sole source of navigation, pre-warning of planned simulation events related to its failing is necessary so that controllers are not completely unfamiliar with the situation and what procedures to implement when such an event occurs.

bp 2-26. Do not try to script operational errors

In real-time simulation, it is useful to study the occurrence and impact of operational errors. There may be a temptation to script certain events to induce such errors. However, this practice is not recommended. Errors such as these should simply be allowed to happen in

order not to bias any results or participant opinions of the concept. Should such errors occur, be careful how you report them. The report should not be of a 'telling tales' nature. Perhaps rather than referring to them as operational errors, the researcher could introduce some adaptation of 'performance scoring'. This approach should enable the same discussion but it appears less negative on the participants. It is also necessary because in any simulation you may get an unfair proportion of operational errors through controller learning or experimenting with the system.

bp 2-27. Consider scripting system-wide events

As well as using scripts that relate to single events in the system being simulated, consider introducing system-wide scripts such as airport closures and system failures. Obviously this could involve considerable planning and may only be done once or twice in a simulation. However, stakeholders are increasingly concerned about the affects of such system-wide events.

bp 2-28. Consider the use of dynamic scripting

In real-time simulation, predetermining scripts may not always be easy, especially when evaluating new systems or if the researcher is unsure of the events beforehand. The dynamic nature of the system means that events can unfold rather differently than planned. A way to adjust when scripts do not go as planned is to use dynamic scripts. For example, consider the example given in Section 3.2.1, which listed particular aircraft expected to be involved in a particular sequence of events. If executing this dynamically, instead of picking a particular aircraft, wait and see how the situation unfolds and pick another aircraft.

However, it should be noted that this dynamic nature also means it can be difficult to accurately reproduce events or compare results between replications. Therefore, it is not recommended in experiments where performance measurements comparisons will be made.

In the early stages of concept development, allowing scenarios to unfold dynamically may help in the development of roles and procedures should these not already be defined.

10 Validation Data Repository

10.1 How the VDR Can Help

The Validation Data Repository (VDR) is a means of managing validation data. It is designed to support the development of a common reference framework with which validation activities can and should be mapped. With regard to 'scenarios,' this has already begun with the introduction of an established information structure that provides:

- Summary information about a scenario (e.g., name, acronym, version, summary, ATM environment description, dates, type)
- Descriptions of relevant operational concepts under test

- Defining characteristics of the scenario (e.g., geographic area, airspace design, traffic samples and profiles, system configurations, task allocations, procedures, event sequences)
- Hyperlinks to detailed source reference documents

The VDR allows different types of scenario to be recorded in a common format, for example, target scenarios, baseline/reference scenarios as well as the test/validation scenarios.

In terms of the re-use of information, the VDR enables mapping of scenarios to exercises, or in other words, provides a means of referencing scenarios. The VDR can also map a scenario to more than one exercise. This means standard scenarios can be defined and linked to many exercises. These exercises may be of different types, for example, fast- and real- time simulations, flight trials, safety case assessments, and economic appraisals.

Information regarding the defining characteristics of a scenario can also be re-used. A scenario may have one or more scenario parameters (the detailed defining characteristics). Scenario parameters may be applicable to more than one scenario, for example, those dealing with airspace characteristics and traffic characteristics. Such parameters need only be defined once within the VDR because they can be made available for linking to many scenarios.

10.2 How the VDR Treats Scenarios

The VDR provides a structure that defines information in a consistent manner to enable scenario comparisons, but also provides sufficient flexibility to allow researchers to make comparisons based on their needs. Figure 3 depicts the information structure relating to scenarios in the VDR.

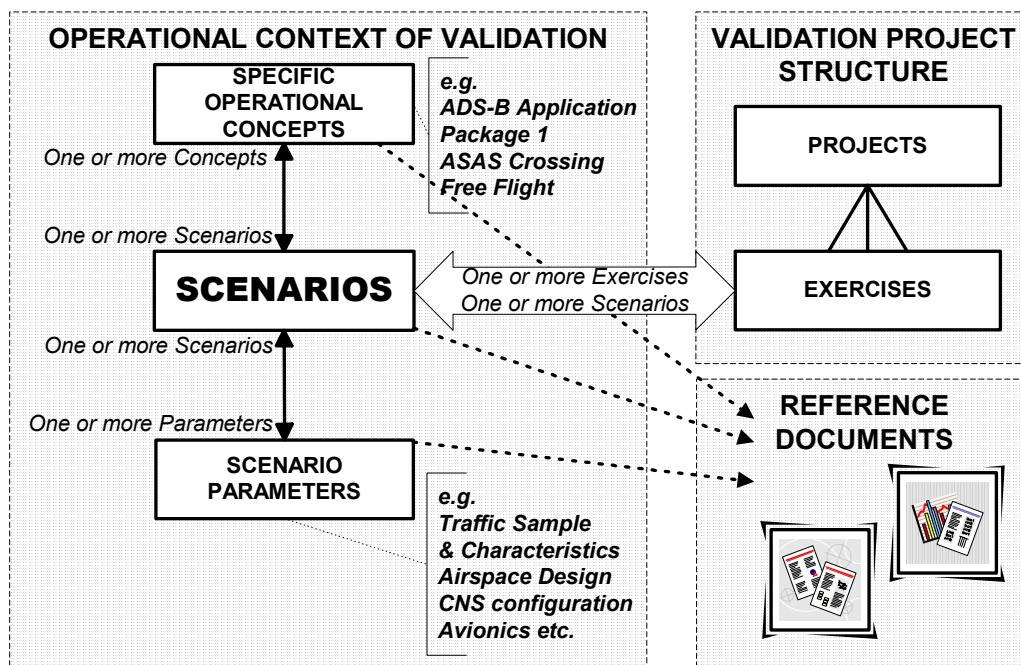


Figure 2 - The role of scenarios in the VDR.

11 Summary of Best Practices in Scenario Design

The collaborative Action Plan 5/Action Plan 9 Workshop brought together a range of practitioners from the U.S. and Europe with experiences in fast-time and real-time simulation to discuss scenario development for purposes of concept validation. The following is a summary of those discussions and the best practices that emerged related to scenario design.

The practitioners' expertise and backgrounds varied; therefore, a common definition of scenario had to first be developed. To satisfy both fast-time and real-time practitioners, a definition of scenario was created for each technique. Scenario uses and scenario objectives were presented, providing a common ground for topic discussions.

Coordination of fast and real-time simulation was a topic that generated much discussion. It was clear that few practitioners had coordinated fast-time and real-time activities. It was also clear that many practitioners of fast-time and real-time simulation were inexperienced in each others' areas of expertise. Increased communication between fast-time and real-time practitioners became one of the first best practices. Standardizing scenarios and clearly stating and documenting design assumptions and the implications of such assumptions for both real-time and fast-time was recommended to allow for data sharing and re-use between the two techniques. Through topic and informal discussion, it was clear that the issue of coordination between fast-time and real-time activities should be addressed further.

Although there are quite a number of factors to consider, the practitioners composed the 28 best practices found in this appendix for scenario development.

Building traffic takes a considerable amount of effort in scenario development. As such, the practitioners identified key considerations related to this activity. For example, with respect to traffic volume in real-time simulation, starting or ending scenarios slowly is not usually efficient and traffic peaks and troughs may be relevant to research. In the case of aircraft performance validation, unrealistic performance can be detected by an experienced controller. The practitioners also addressed building traffic to represent growth based on airport and city pair projections, translating yearly forecasts into daily and hourly operations, and trying to identify the appropriate aircraft types and mixes.

Scripting an event is deliberately introducing a disturbance into the system. In real-time simulation, this would be accomplished by planning a specific type of event and introducing it during the simulation run to induce some kind of human response. In fast-time simulation, a scripted event is usually introduced at a specific time during a simulation run. The best practices resulting from the workshop that relate to scripted events mostly deal with real-time simulation. Best practices include the following: Planning more scripted events than needed ensures desired results. Preparing participants as to what to expect is a common practice, but one should keep this to a minimum. Intentional scripting of operational errors should not occur, operational errors should happen naturally in the simulation. Consideration should be taken to script system wide events.

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Practitioners should keep in mind that the VDR is a valuable tool that provides a means of storing, sharing and disseminating data, including scenario information, and it establishes a common reference framework with which validation activities can and should be mapped. The VDR provides an established information structure for managing scenarios.

Based on feedback surveys, most practitioners felt that the workshop was useful and that other workshops should be developed in the future. Metrics and measures, reporting of results, and more specific scenario development topics (separate fast and real-time) were some of the suggestions for future workshop topics. Bringing together practitioners from different backgrounds to discuss "best practices" was a challenge, but overall the experience was a successful one.